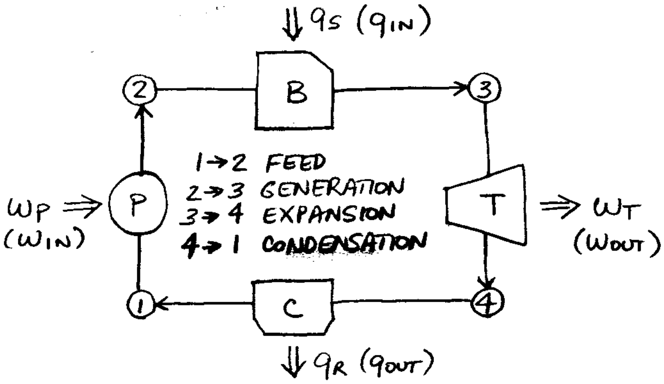
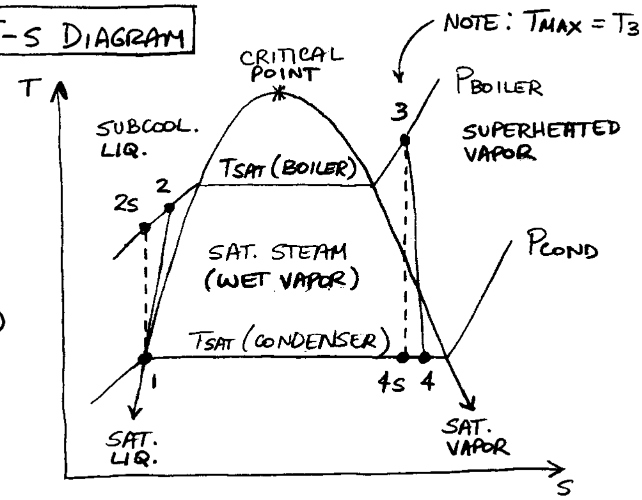
ANALYSIS OF STEAM CYCLE

COMPONENT DIAGRAM



T-S DIAGRAM



NOTE: THE ALTERNATE DIAGRAM IS THE h-s DIAGRAM (MOLLIER DIAGRAM) – IT IS ONLY USEFUL FOR PROCESS 3→4

CYCLE THERMAL EFFICIENCY

$$\eta_{TH} = \frac{W_{NET}}{q_S} = \frac{W_T - W_P}{q_S}$$

OR

$$\eta_{TH} = \frac{q_{NET}}{q_S} = \frac{q_S - q_R}{q_S}$$

STATE POINT CALCULATIONS

① "CONDENSATE EXITS CONDENSER (OR ENTERS FEED PUMP)"

a) DETERMINE IF ① IS SAT. LIQ. OR SUBCOOLED LIQ.

— IF SAT. LIQ., THEN:

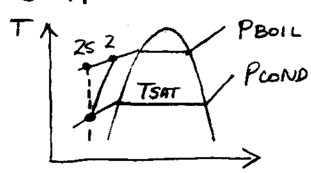
$$h_1 = h_f \text{ @ } p_{COND} \longrightarrow \text{[TABLE 2]}$$

OR

$$h_1 = h_f \text{ @ } T_{SAT}\text{(CONDENSER)} \longrightarrow \text{[TABLE 1]}$$

— IF SUBCOOLED LIQ, THEN:

$$h_1 = h_f \text{ @ } T_1 \longrightarrow \text{[TABLE 1]}$$



① IS SUBCOOLED

$T_1 = T_{SAT}\text{(COND)} - \text{(CONDENSATE DEPRESSION)}$

b) LOOK UP v_1 $\left[\frac{FT^3}{LBm}\right]$ WHETHER ① IS SAT. LIQ. OR SUBCOOLED LIQ.

(2s) "FEEDWATER EXITS FEED PUMP (OR ENTERS BOILER)"

— THIS IS THE ISENTROPIC (IDEAL) PUMP EXIT STATE POINT

$$h_{2s} = h_1 + W_P = h_1 + v_1 (p_2 - p_1) \frac{144}{778}$$, ASSUMES p = [PSIA]

↑ ISENTROPIC PUMP WORK

② "FEEDWATER EXITS FEED PUMP (OR ENTERS BOILER)"

— THIS IS THE ACTUAL (REAL) PUMP EXIT STATE POINT

$$\eta_P = \frac{W_P\text{(IDEAL)}}{W_P\text{(REAL)}} = \frac{h_{2s} - h_1}{h_2 - h_1} \Rightarrow \text{SOLVE FOR } h_2$$

STATE POINT CALCULATIONS

③ "STEAM EXITS THE BOILER (OR ENTERS THE TURBINE)"

a) DETERMINE IF ③ IS SAT. VAPOR OR SUPERHEATED (S/H) VAPOR

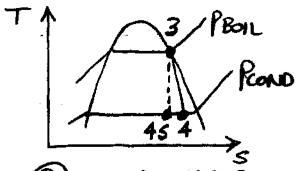
— HOW TO TELL IF S/H OR NOT?

ANS: COMPARE GIVEN STEAM TEMP (T_3) TO T_{SAT} (BOILER)

$\Rightarrow$ IF $T_3 = T_{SAT}$ (BOILER) IT IS SAT. VAPOR

$\Rightarrow$ IF $T_3 > T_{SAT}$ (BOILER) IT IS S/H VAPOR

— IF SAT. VAPOR, THEN:



③ IS SAT. VAPOR

$h_3 = h_g$ @ p_{BOIL} ⟶ [TABLE 2]

OR

$h_3 = h_g$ @ T_{SAT} (BOILER) ⟶ [TABLE 1]

— IF S/H VAPOR, THEN:

$h_3 = h$ (S/H, P_{BOIL}, T_3) ⟶ [TABLE 3]

b) LOOK UP $s_3 \left[\frac{Btu}{LBm\,°R}\right]$ WHETHER ③ IS SAT. VAPOR OR S/H VAPOR

④s "STEAM EXITS THE TURBINE (OR ENTERS THE CONDENSER)"

— THIS IS THE ISENTROPIC (IDEAL) TURBINE EXIT STATE POINT

a) FIRST, REALIZE $s_3 = s_{4s}$

b) THEN <u>STEP 1</u> $s_{4s} = s_f + x_{4s}(s_{fg}) \Rightarrow$ SOLVE FOR x_{4s} (STEAM QUALITY)

NOTE: s_f AND s_{fg} FROM TABLE 2 (@ P_{COND}) <u>OR</u> FROM TABLE 1 (@ T_{SAT} (COND))

c) FINALLY <u>STEP 2</u> $h_{4s} = h_f + x_{4s}(h_{fg}) \Rightarrow$ SOLVE FOR h_{4s}

NOTE: h_f AND h_{fg} FROM TABLE 2 (@ P_{COND}) <u>OR</u> FROM TABLE 1 (@ T_{SAT} (COND))

④ "STEAM EXITS THE TURBINE (OR ENTERS THE CONDENSER)"

— THIS IS THE ACTUAL (REAL) TURBINE EXIT POINT

$$\eta_T = \frac{w_T(\text{REAL})}{w_T(\text{IDEAL})} = \frac{h_3 - h_4}{h_3 - h_{4s}} \Rightarrow \text{SOLVE FOR } h_4$$

BOILER EFFICIENCY $\eta_{BOIL} = \dfrac{\text{SMALLER}}{\text{BIGGER}} = \dfrac{\text{STEAM HEAT RATE}}{\text{FUEL HEAT RATE}} = \dfrac{\dot{m}_{STM}(h_3 - h_2)}{\dot{m}_{FUEL}(HHV)}$ ← q_s

POWER POWER ≡ RATE OF WORK ($\dot{W}$)

SO, POWER (NET) OF A STEAM PLANT: $\dot{W}_{NET} = \dot{m}_{STM}(w_{NET})$ ← $w_T - w_P$

POWER OF THE TURBINE: $\dot{W}_T = \dot{m}_{STM}(w_T)$ ← USUALLY IN [HP]

POWER REQUIRED FOR PUMP: $\dot{W}_P = \dot{m}_{STM}(w_P)$ ← USUALLY IN [KW]

SATURATION PRESSURES/TEMPERATURES

IF A PROBLEM GIVES A PRESSURE WHICH IS NOT SPECIFICALLY LISTED IN TABLE 2, TRY TO FIND A VERY CLOSE PRESSURE IN TABLE 1 INSTEAD. THEN USE THE CORRESPONDING TEMPERATURE IN TABLE 1 TO LOOK UP PROPERTIES.